Long-term Air Pollution and Brain: results from the Ruhr Area observational studies

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WG Environmental Epidemiology

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Projekte Arbeits- und Sozialmedizin

Umweltepidemiologie / Environmental Epidemiology ^

AG Umweltepidemiologie / Environmental Epidemiology

Our mission is to identify harmful exposures for human health in the environment and to contribute to prevention of environmentally-related disease. We do so by conducting epidemiological studies of short- and long-term effects and translate these findings to policy makers and the public. Our main focus is on cardio-metabolic disease, respiratory disease and mental health. We are part of several large national and international consortia

Head of Group

Prof. Dr. Barbara Hoffmann MPH (Profil)

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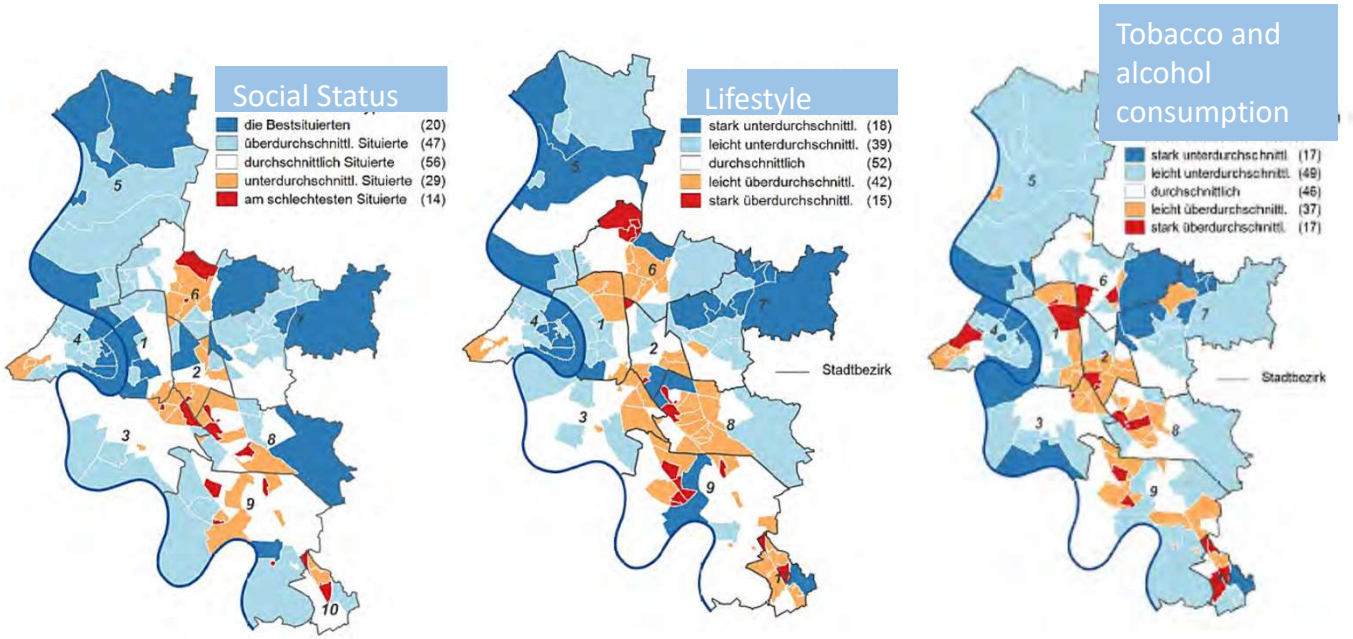
Join effect of risk factors

Heinrich Heine Universität Düsseldorf

Risk factors accumulate spatially and influence each other

- socio-economic
- lifestyle-related
- environmental



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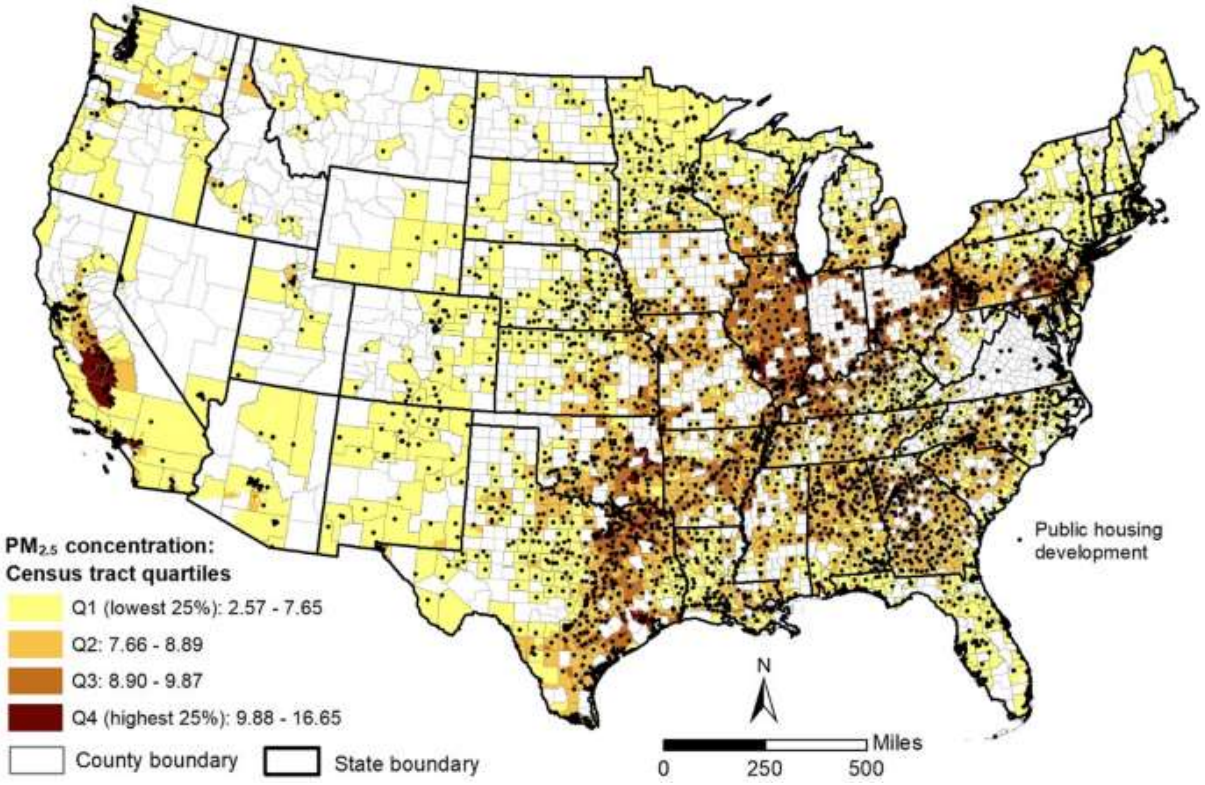
Inequality



PHD locations, units, and residents are significantly overrepresented in neighborhoods with greater PM2.5 exposure.

Significantly higher percentages of Black, Hispanic, disabled, and extremely low-income households reside in PHDs with greater PM2.5 exposure.

Source: Chakraborty J et al. 2022

Inequality

Areas with higher exposure to pollutants are often socio-economically deprived, putting a double burden on the people living where and creates a systematic inequality in the society

Smog crisis in the Ruhr area, 3.-7.12.1962

- Suspended particulate matter
  2,400 µg/m^3 (annual mean 2017 < 40 µg/m^3)
- Mortality - increase of approx. 30%

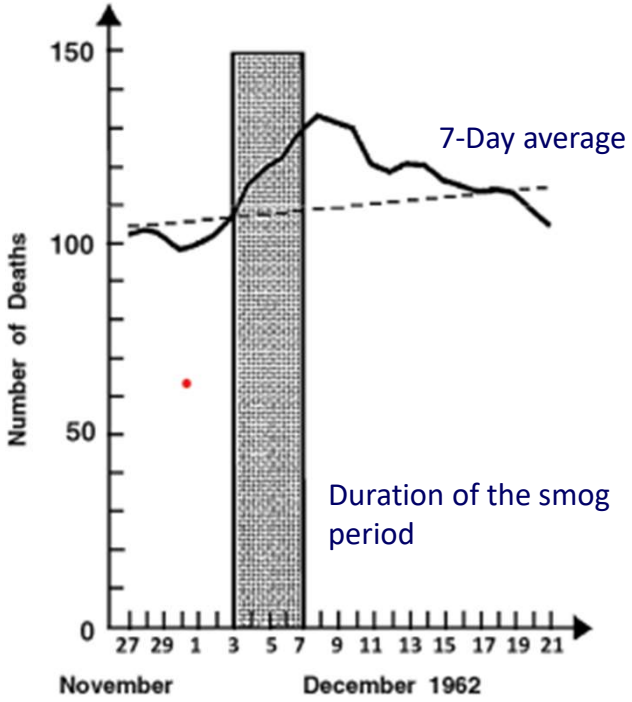


Figure 2. Number of deaths (sliding average over seven days) during the smog episode in the Ruhr area in December 1962 [14]. The grey column marks the duration of the smog period.

Further smog episodes 1/79; 1/82; 1/85; 1/87

Source: Bruckmann P et al. 2014

Pollution and health: a progress update

Richard Fuller, Philip J Landrigan, Kalpana Balakrishnan, Glynda Bathan, Stephan Bose-O'Reilly, Michael Brauer, Jack Caravanos, Tom Chiles, Aaron Cohen, Lilian Corra, Maureen Cropper, Greg Ferraro, Jill Hanna, David Hanrahan, Howard Hu, David Hunter, Gloria Janata, Rachael Kupka, Bruce Lanphear, Maureen Lichtveld, Keith Martin, Adetoun Mustapha, Ernesto Sanchez-Triana, Karti Sandilya, Laura Schaefli, Joseph Shaw, Jessica Seddon, William Suk, Martha María Téllez-Rojo, Chonghuai Yan

9 million deaths per year

One in six deaths worldwide

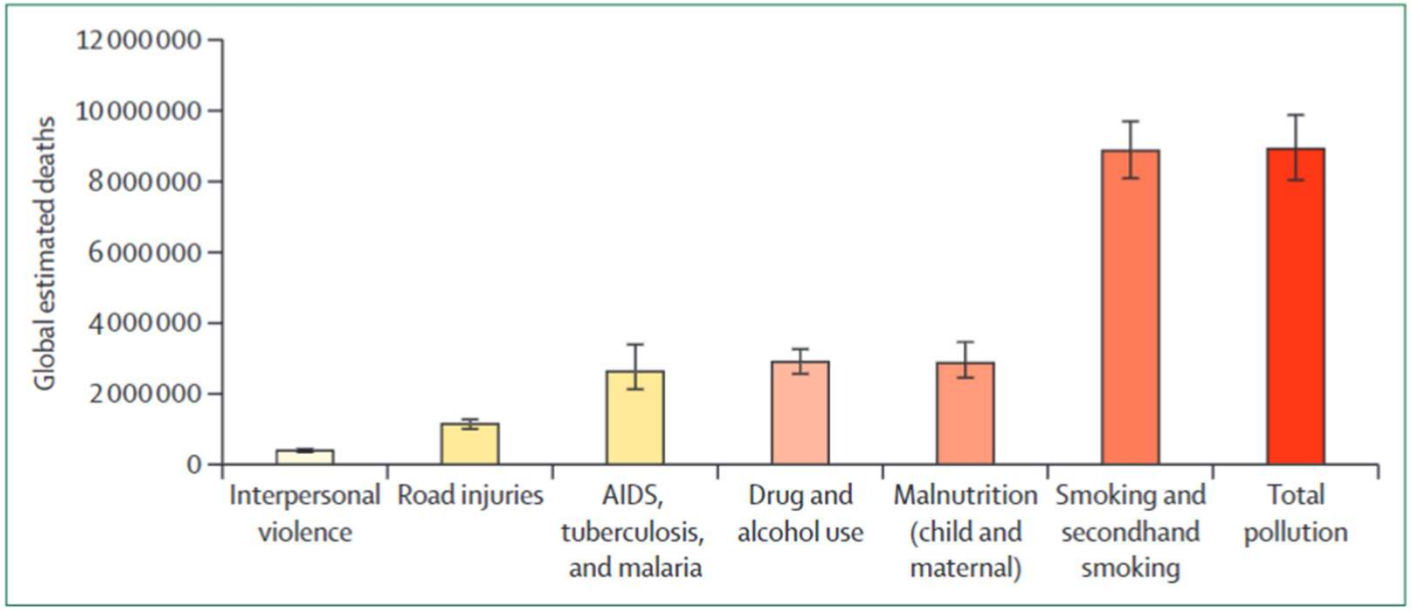
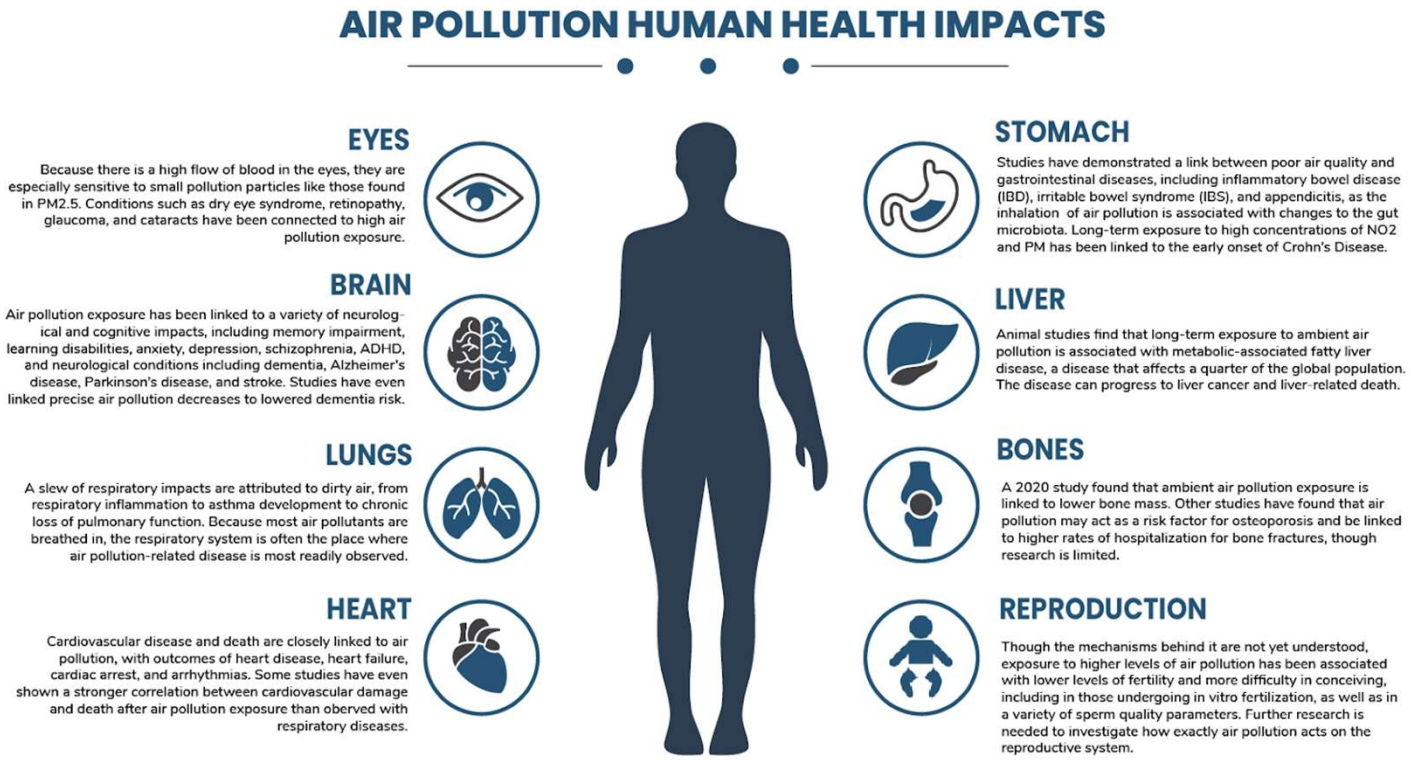


Figure 1: **Global estimated deaths by major risk factor or cause**
Data from Institute for Health Metrics and Evaluation and Global Burden of Diseases, Injuries, and Risk Factors Study 2019.[6] Error bars are 95% CI.

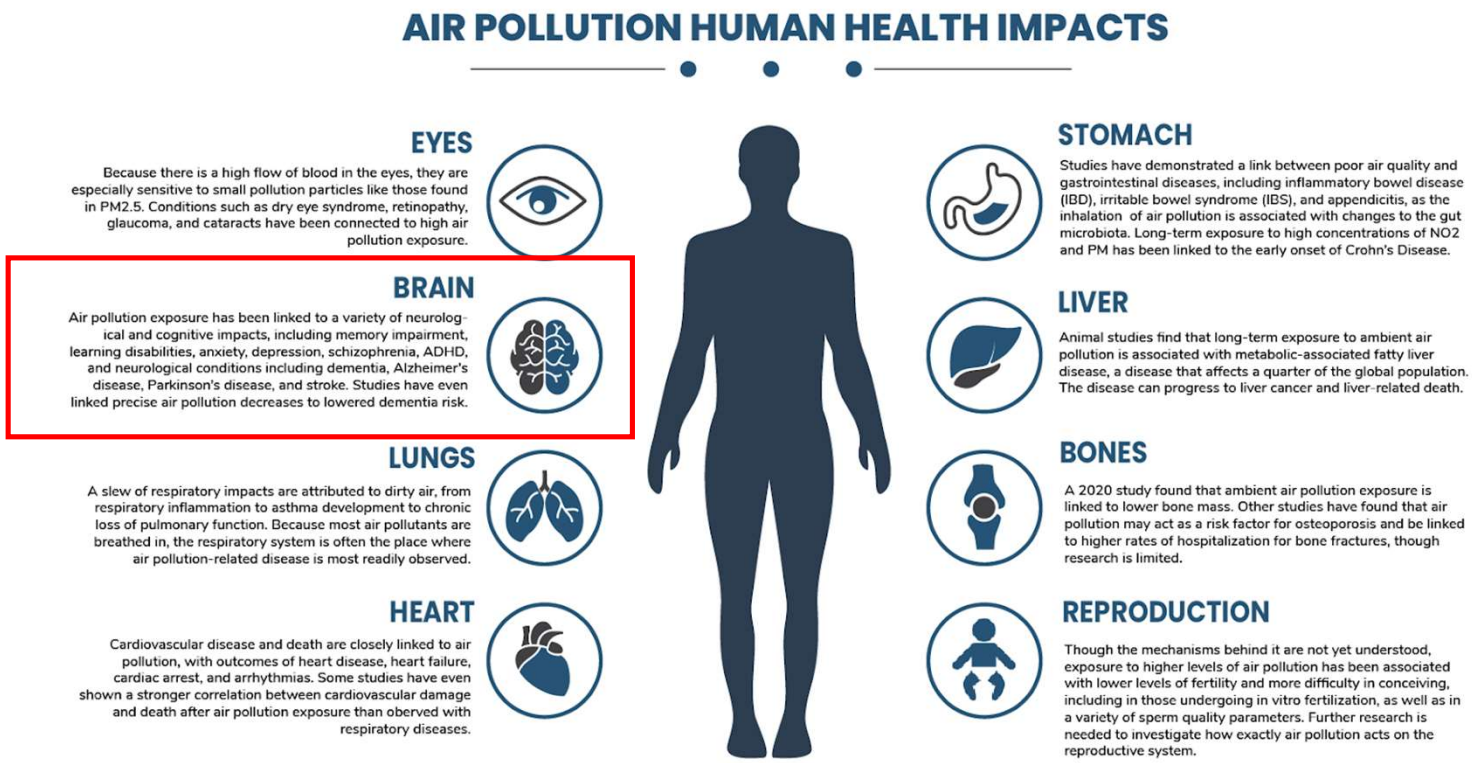
Source: Fuller R et al. 2022

Why is it important?



https://www.clarity.io/blog/deep-dive-health-impacts-of-air-pollution

Why is it important?



https://www.clarity.io/blog/deep-dive-health-impacts-of-air-pollution

Why is it important?

Exposure to air pollutants ($PM_{2.5}$ and NO_x/NO_2)

~ higher risk of dementia

~ worse cognitive performance

Ultrafine particles (UFP, <10nm) showed neurotoxic effect (only animal studies)

Exposure to noise

~ cognitive impairment

~ higher risk of dementia

Objectives

Do long-term exposure to air pollution and ambient noise harmful to a brain for elderly population?

Study population

Heinz Nixdorf Recall (Risk Factors, Evaluation of Coronary Calcium and Lifestyle) study

- Longitudinal prospective population-based study
- Essen, Bochum und Mülheim a. d. Ruhr

- **Baseline** (T_0, 2000-03):

  4814 Participants, 45-75 years old

- **First Follow-up** (T_1, 2005-08):

  4157 Participants, 50-80 years old

- **Second Follow-up** (T_2, 2010-15):

  3087 Participants, 55-86 years old

Study population

HNR-Multigeneration Study (HNR-MGS)

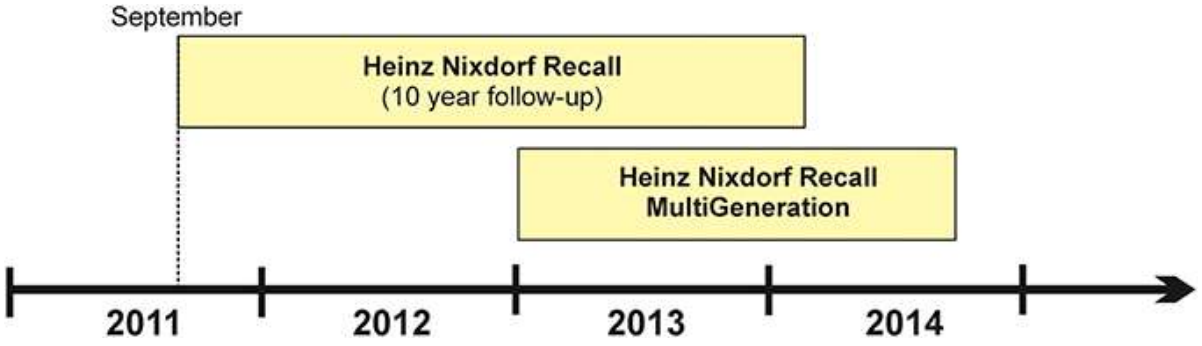
partners and children of HNR participants

- 2013-2016
- 1237 partners and 1660 adult children
- 18-90 years old

1000BRAINS Study

recruited from the T_2 of HNR and HNR-MGS

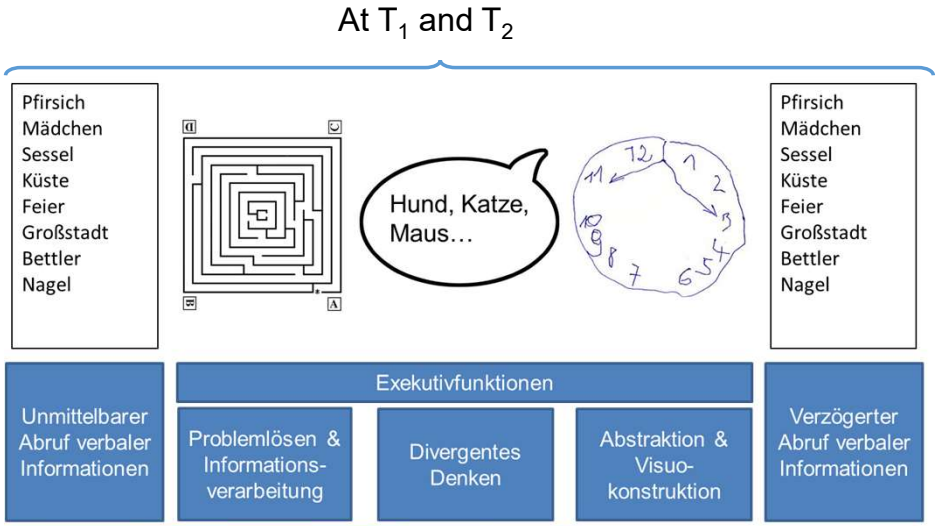
- 2011-2016
- 1000 Participants
- 55-85 years old
- assessing the variability of brain structure and function in the course of normal aging



Source: Caspers S et al. 2014

Cognitive tests/ neuropsychological assessment

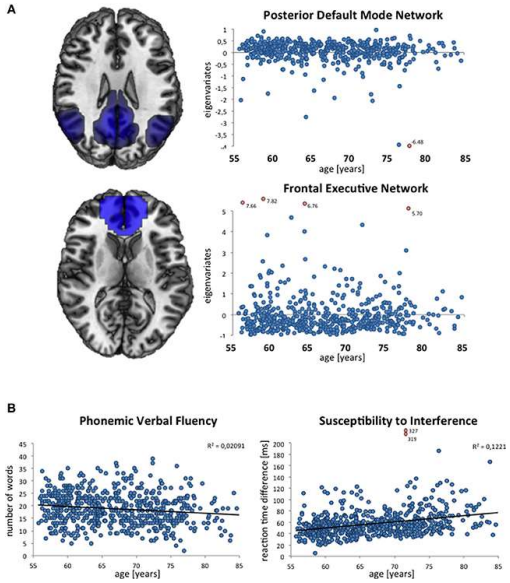
- verbal fluency
  (Verbal Fluency Test, semantic category “animals”, number of words within one minute)
- problem solving/speed of processing
  (Labyrinth Test, time in seconds needed to complete the task)
- immediate and delayed verbal memory
  (Verbal Memory Test, two parts, eight-word list, performance measured as number of words recalled in each trial)
- abstraction/visual-spatial organization
  (Clock-Drawing Test, performance was rated from 1 (perfect clock) to 6 (poor performance))



Magnetic Resonance Imaging acquisition

Research Centre Jülich

3T Siemens Tim-TRIOMRI scanner with a 32-channel head coil



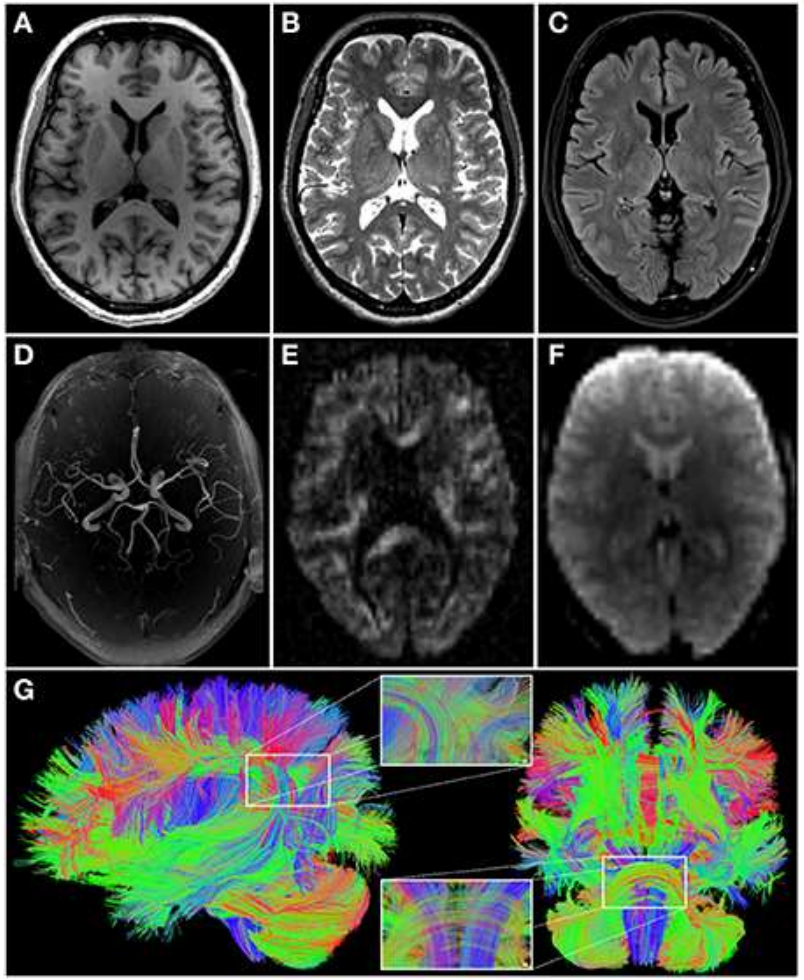


Figure source: Caspers S et al. 2014

Air Pollution in the HNR Study

- EURAD-CTM

Chemistry Transport Model
Simulates transport, chemical transformation, and deposition of tropospheric constituents.

- ESCAPE-LUR

Land Use Regression Model
Based on measured pollutant concentrations from monitoring sites and other predictors

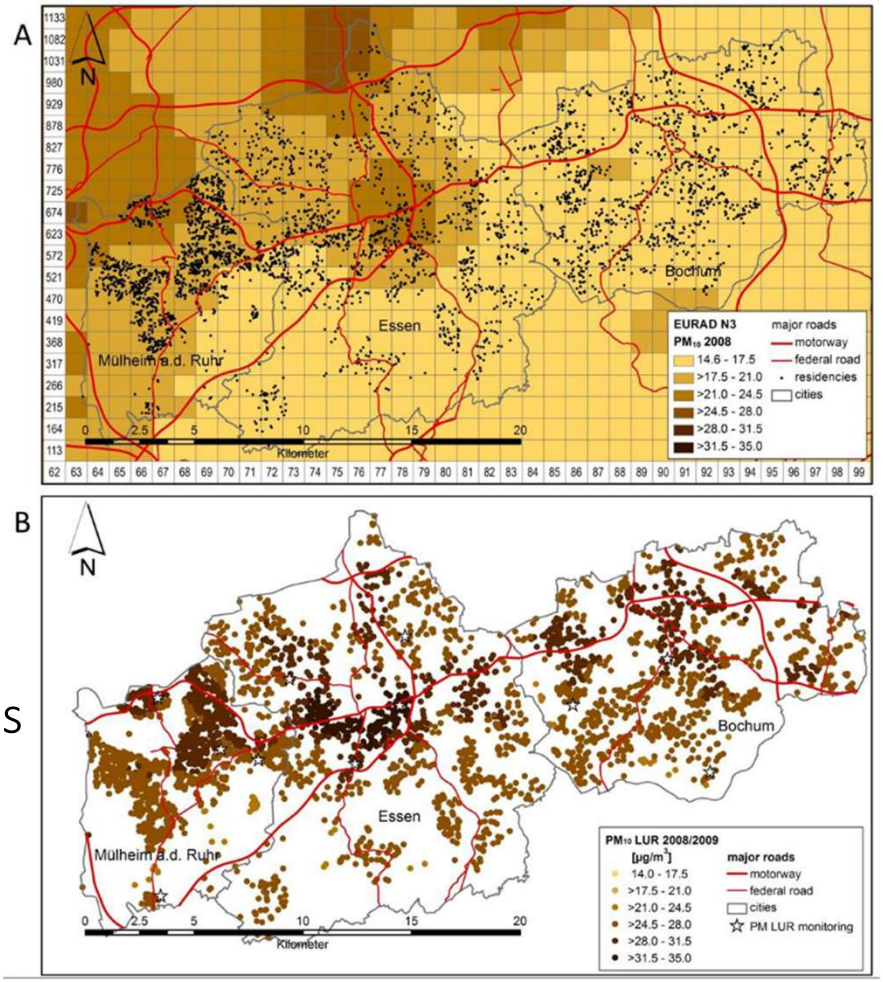
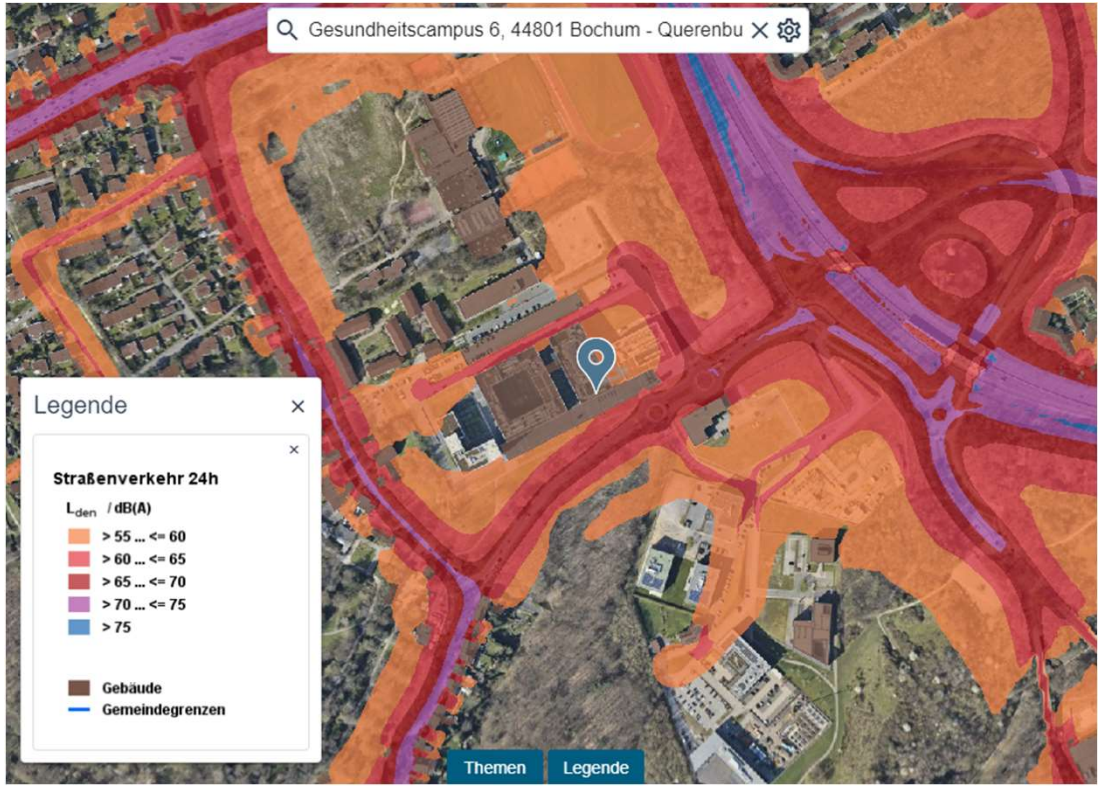


Figure source: Hennig F et al. 2016

Noise pollution in the HNR Study

Noise maps: https://www.umgebungslaerm-kartierung.nrw.de/
Modeled according to the European Union Directive (2002/49/EC) A-weighted decibels [dB(A)]



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Findings

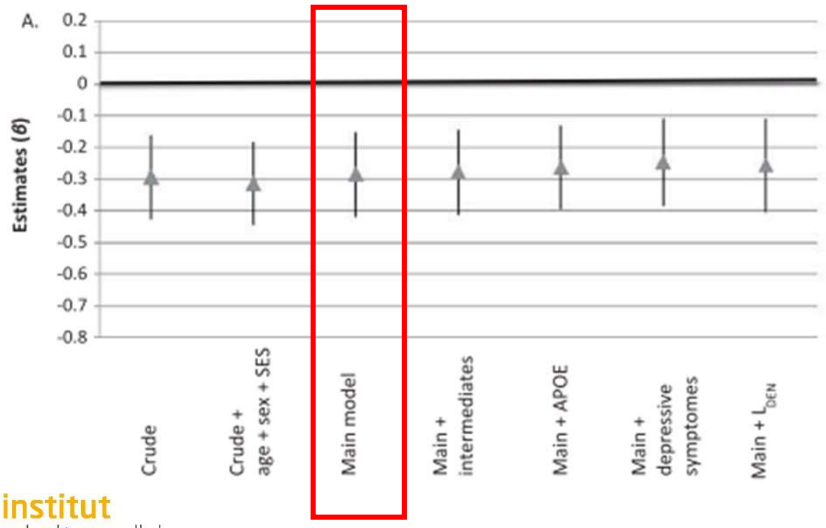
Findings

Cross-sectional association of chronic exposure to **air pollution** and **traffic noise** with **cognitive performance**

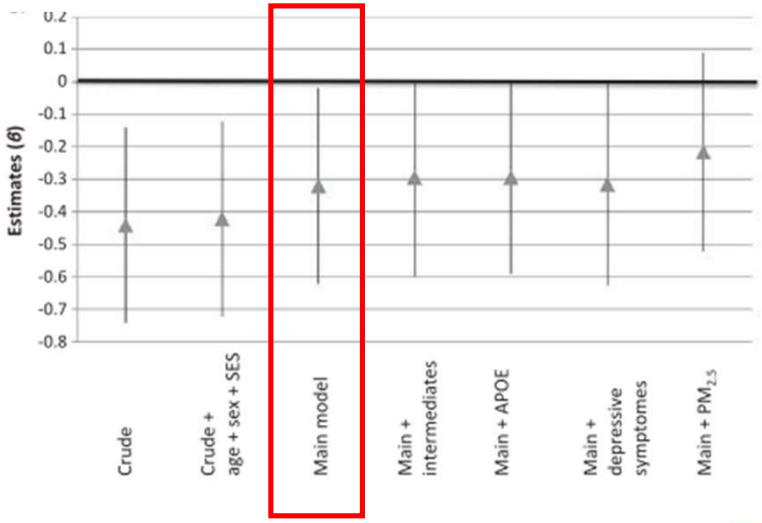
Data: T_1 HNR (2006–2008)

Adjusted to age, gender, socio-economic status, environmental tobacco smoke, alcohol consumption, smoking status, ETS, any regular physical activity , and BMI

$PM_{2.5}$ ~ Global score



L_{den} (24 h man Noise) ~ Global score



↑ traffic-related AP and traffic noise ~↓ worse performance

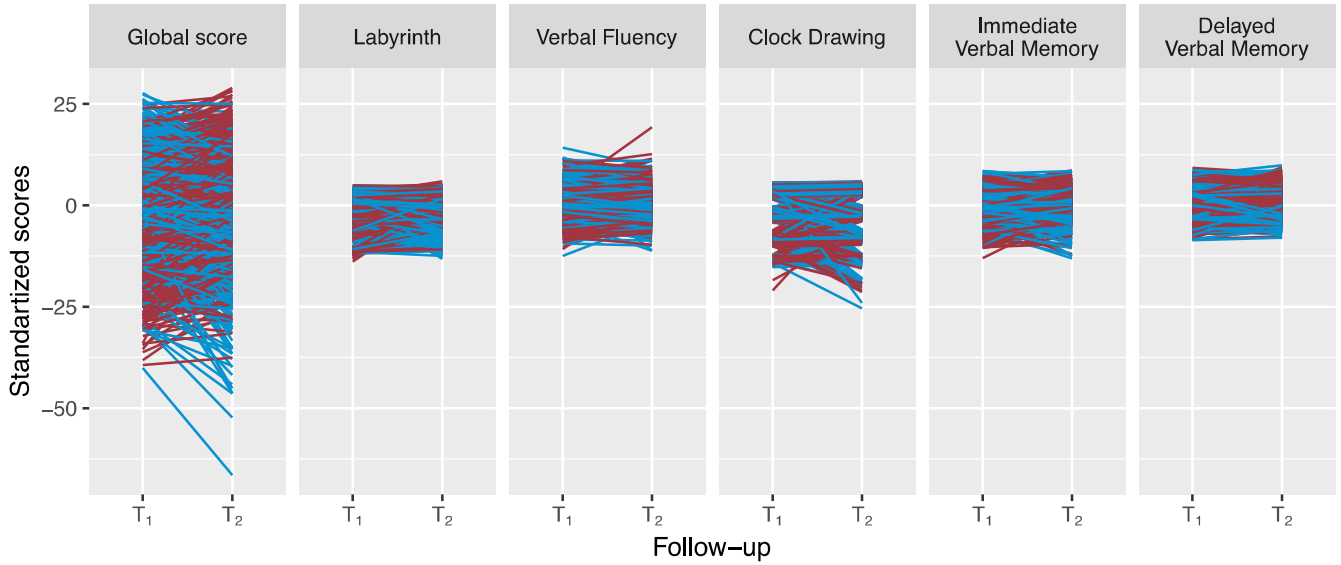
Source: Tzivian L et al. 2017

Findings

Longitudinal association of chronic exposure to **air pollution** and **traffic noise** with **cognitive performance**

Data: T_1 and T_2 HNR

Adjusted to age, gender, socio-economic status, environmental tobacco smoke, alcohol consumption, smoking status, ETS, any regular physical activity , and BMI

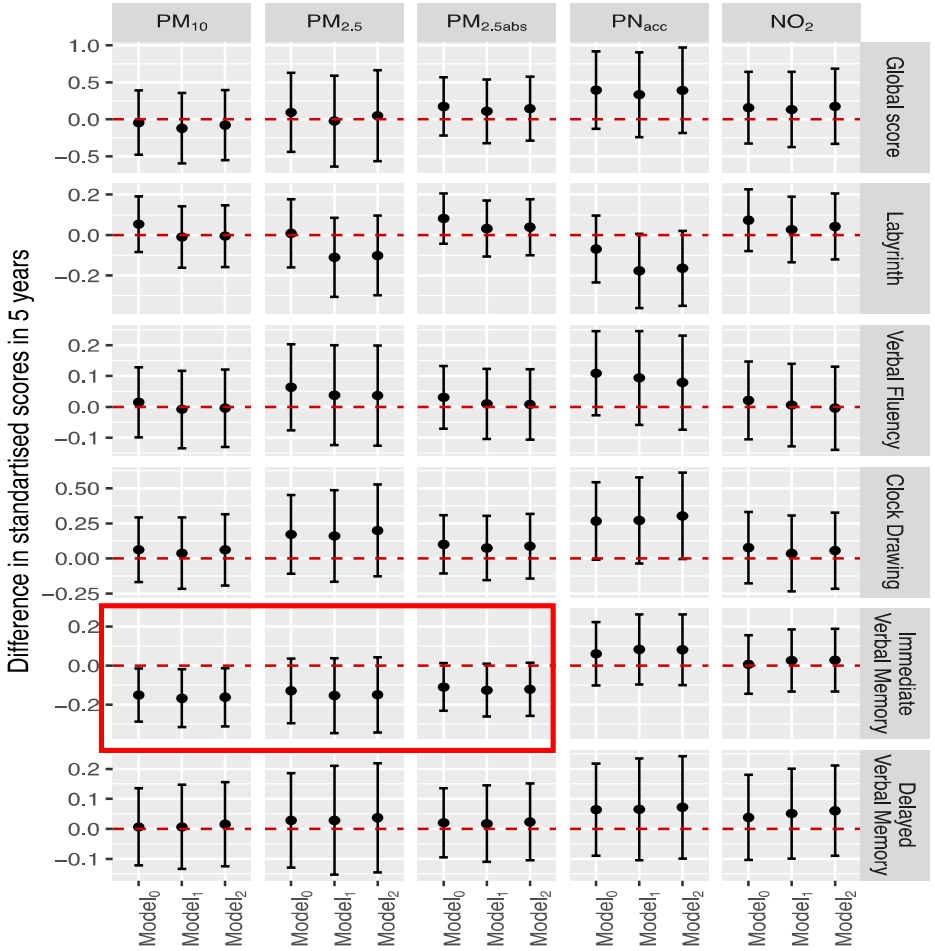


Source: unpublished

Findings

AP estimates were calculated per IQR and are shown with 95% confidence intervals.

↑ AP and noise ~↓ faster decline in the performance

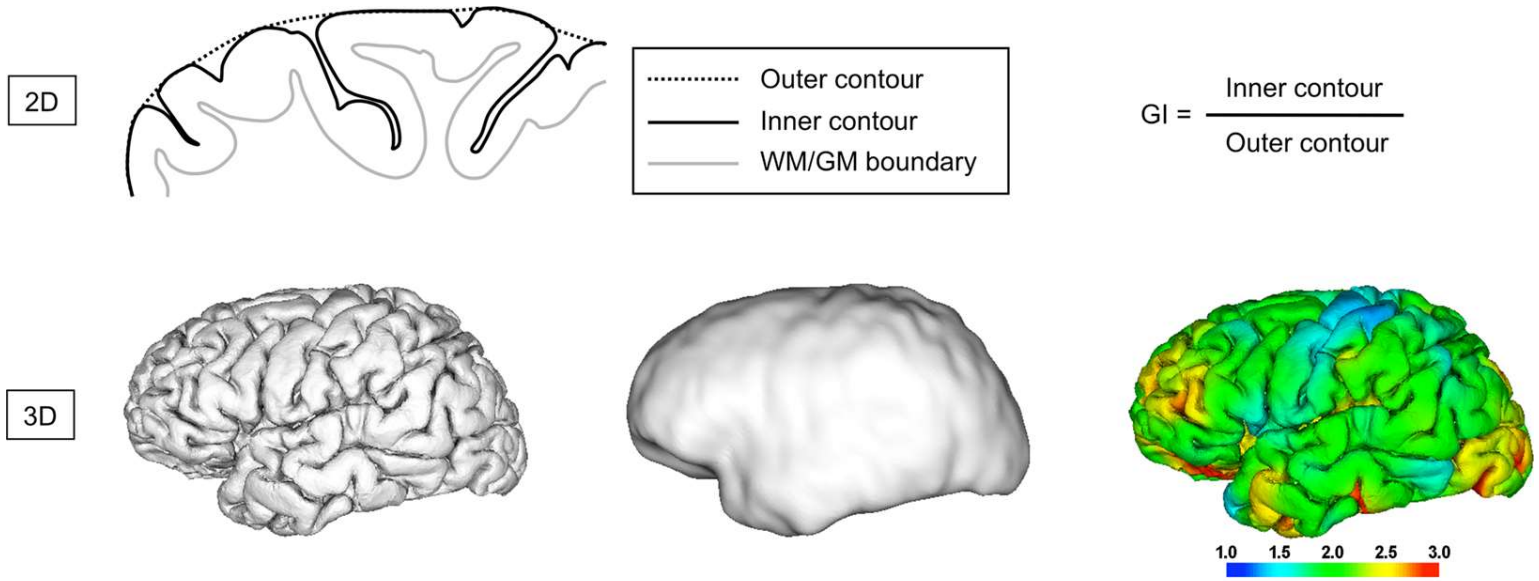


The negatives difference in standardized scores corresponds to a more rapid than expected decline in cognitive performance; the positive difference in standardized scores means corresponds to a slower than expected decline in cognitive performance.

Findings

Cross-sectional association of chronic exposure exposure to **air pollution** and **noise** with **atrophy in brain** observed in the physiologically aging brain

Data: 1000BRAINS



Source: Rizkallah M et al. 2018

Findings

Cross-sectional association of chronic exposure exposure to **air pollution** and **noise** with **atrophy in brain** observed in the physiologically aging brain

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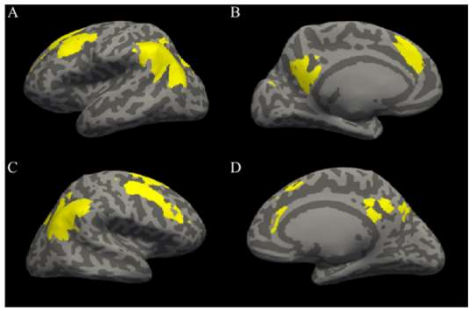
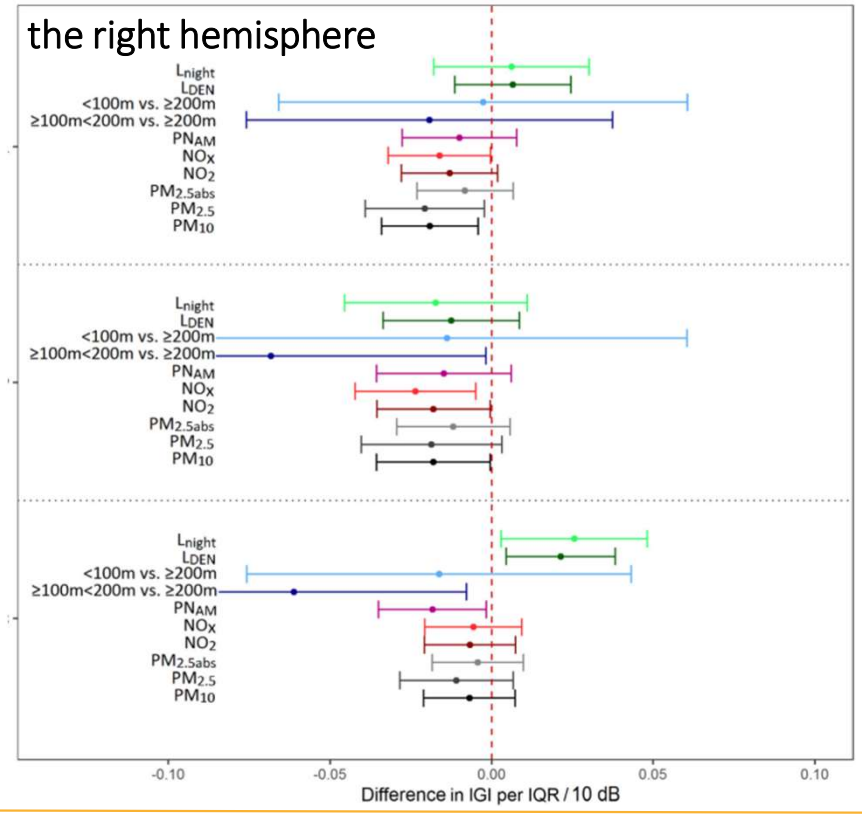




Fronto–parietal network (Language Domain, Short-Term/Working Memory Domain):

↑ AP ~↓local gyrification index (right hemisphere)

Both chronic air pollution and noise exposure may influence the physiological aging process of the brain

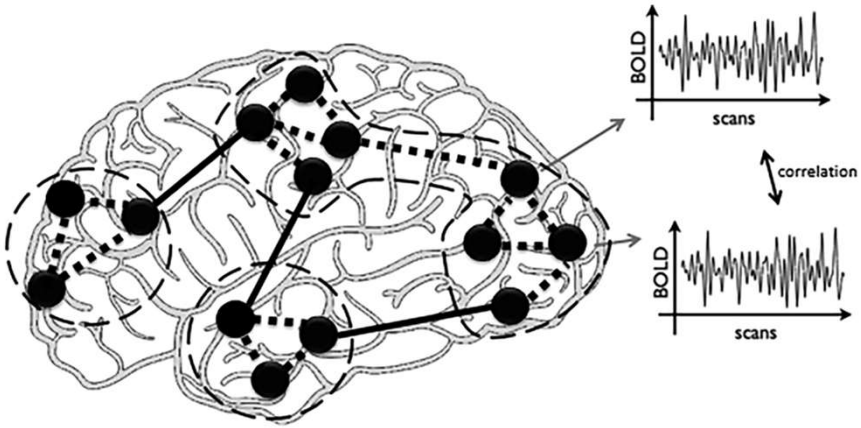
Source: **Nußbaum R** et al. 2020

Findings

Cross-sectional association of chronic exposure exposure to **air pollution** and **noise** with global functional brain organization

Functional brain organization is characterized by a balance between densely connected regions within networks together with few long-range connections between more remote regions and networks

With age, a pattern of **segregation** (decrease in connectivity strength) between anatomically close brain regions and **integration** (increase in connectivity strength) between functionally related brain regions emerges.

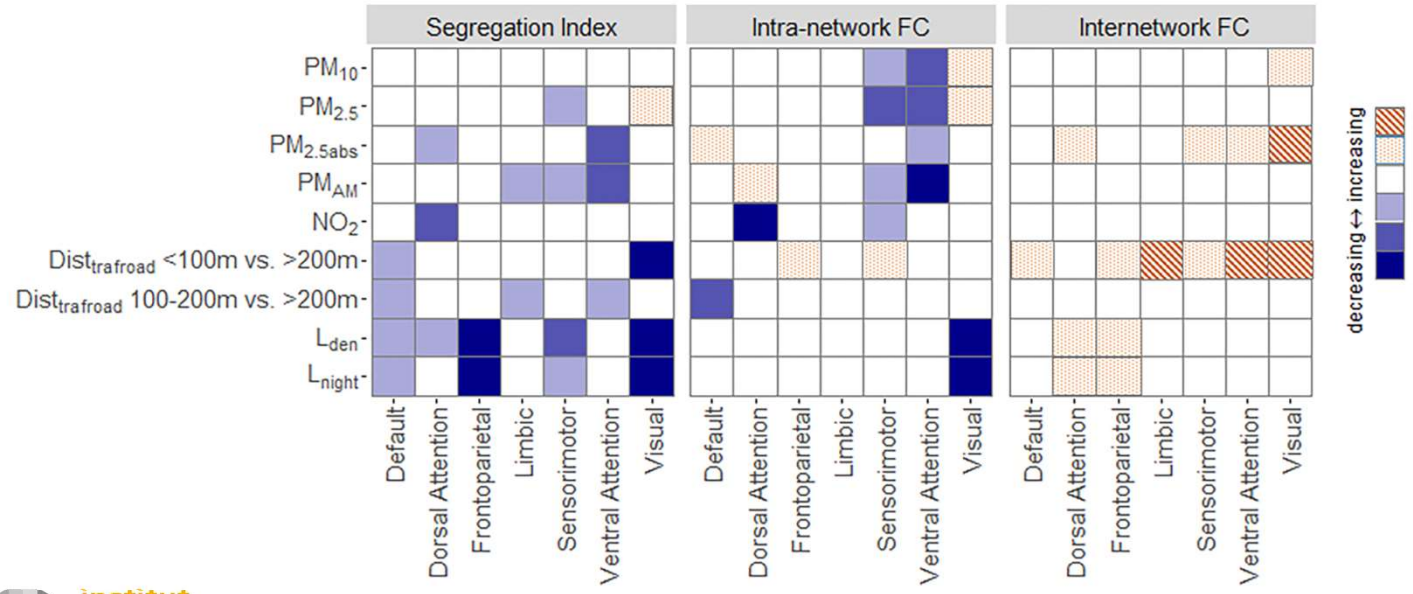


Source: **Glaubitz L** et al. 2022

Findings

Cross-sectional association of chronic exposure exposure to **air pollution** and **noise** with global functional brain organization

Data: 1000BRAINS



high air pollution and noise levels might favor an age-like change in functional brain organization

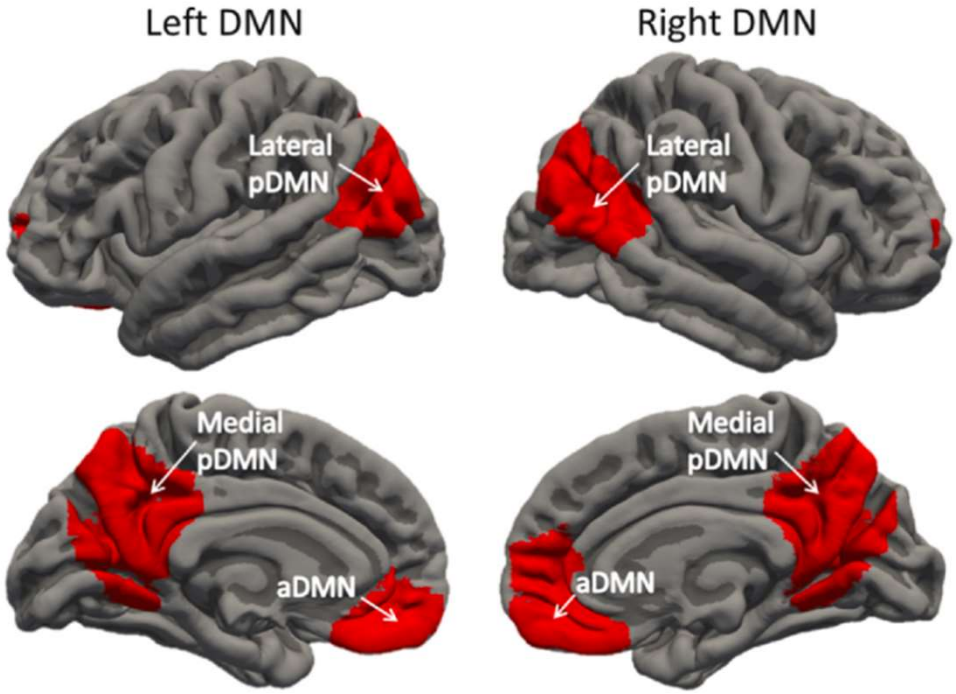
Source: Glaubitz L et al. 2022

Findings

Cross-sectional association of chronic exposure exposure to **air pollution** and **noise** with **structural measures of the DMN** (cortical thickness, lGI)

Default Mode Network (DMN) is an important functional network that plays a large role in mental functions, such as self-referential thinking, and memory recall; it is activated during the resting state.

Aging of this network is associated with changes in functional connectivity, including a posterior to anterior shift (PASA) where frontal brain regions take over additional functions to compensate for decreased activity in posterior regions.

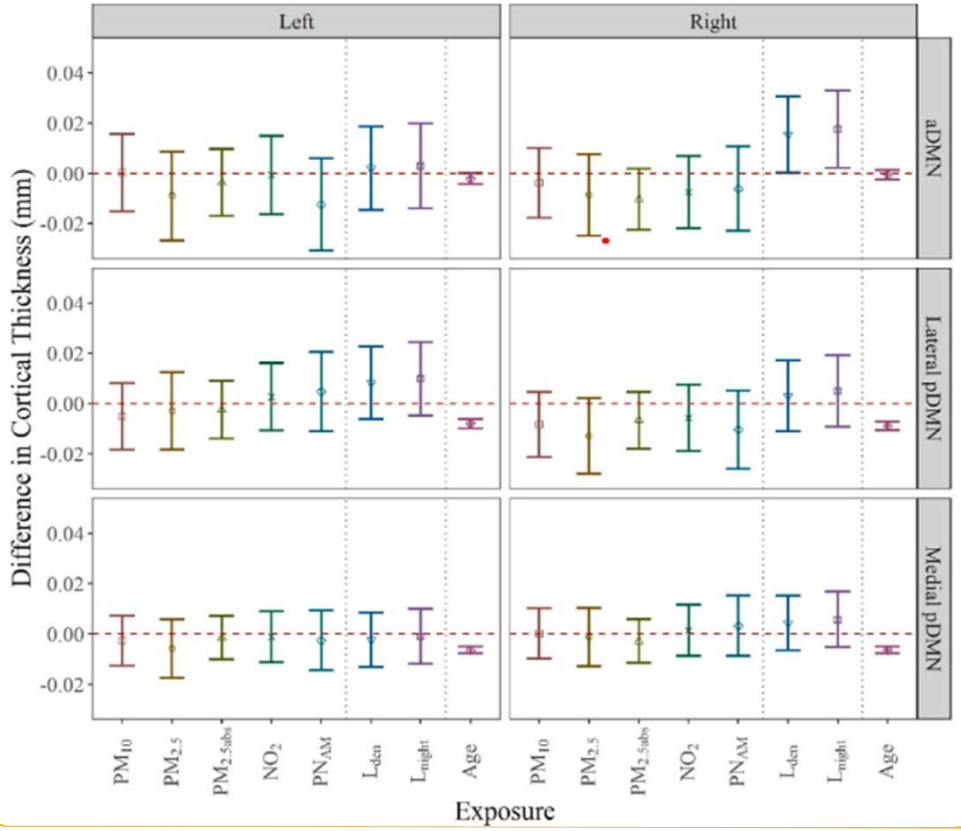


Source: **Lucht S** et al. 2022

Findings

Cross-sectional association of chronic exposure exposure to **air pollution** and **noise** with **structural measures of the DMN** (cortical thickness, lGI)

Data: 1000BRAINS



Fronto–parietal network (Language Domain, Short-Term/Working Memory Domain):

↑ AP ~↓cortical thickness in right DMN

Source: Lucht S et al. 2022

Conclusion

- The higher exposure to air pollution and noise is associated with changes in brain and in cognitive function similar to ageing

Conclusion

- The higher exposure to air pollution and noise is associated with changes in brain and in cognitive function similar to ageing

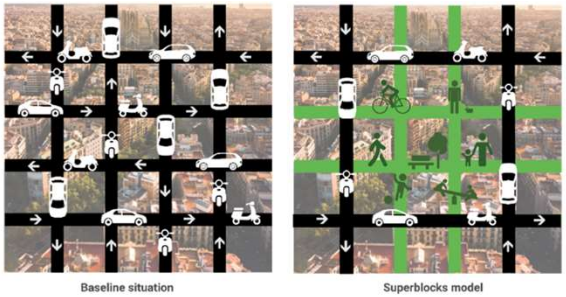
- Areas with higher exposure to pollutants are often socio-economically deprived, putting a double burden on the people living where and creates a systematic inequality in the society

- The urgent need to take into account exposure to air pollutants and noise in urban settings whenever urban interventions are planned

- reducing emissions of air pollution and noise, for example by providing opportunities for active transport, will positively influence health, quality of life and social equality in urban settings

Solutions

a) low traffic neighbourhood, London



b) Superblock, Barcelona

c) 15-minute city, Paris

d) Car free Vauban, Freiburg, Germany

- Structural-building
- Lifestyle-related "active transport"(physical movement)
- Technical

Solutions are available - they just need to be applied!

Source: Nieuwenhuijsen MJ 2021

Thank you!

https://www.ccacoalition.org/en/news/world-health-organization-releases-new-global-air-pollution-data